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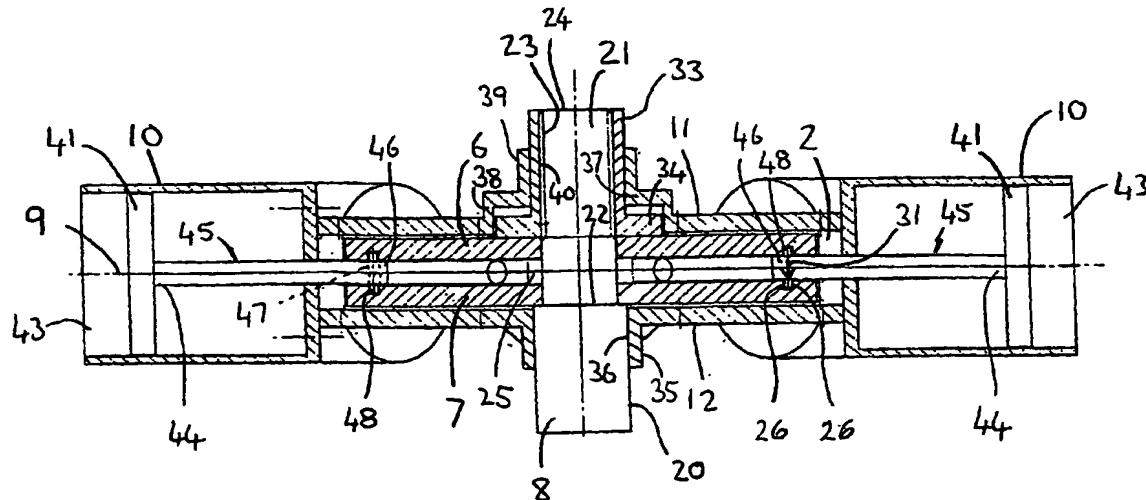
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(54) Title: RADIAL ENGINE



WO 02/088524 A1

(57) Abstract: The invention relates to a radial engine (1). The engine includes an engine block (2) having a central aperture (15). A drive shaft (8) extends through the aperture and a planar cam plate (6, 7) is fixedly mounted on the shaft. A pair of spaced opposed walls (26) extend from the surface of the plate to define a substantially "figure 8" shaped continuous loop (27). At least one cylinder (10) is fixed with respect to the block and extends outwardly from the block. A reciprocating piston (41) is slidably mounted within the cylinder (10). A connecting rod (45) is fixedly connected at one (44) end to the piston (41) and includes an opposite free end (46). A cam follower (48) is translationally fixed with respect to the connecting rod (45). The cam follower is engaged with at least one of the walls (26), such that reciprocation of the piston (41) rotates the plate (6, 7) and the shaft (8).

TITLE: RADIAL ENGINEFIELD OF THE INVENTION

The present invention relates to engines and particularly to radial engines. It has been developed primarily for use as an internal combustion engine in which the pistons 5 are configured to drive the crank. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND OF THE INVENTION

The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its significance to be properly appreciated. 10 Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an admission that such art is widely known or forms part of common general knowledge in the field.

There are various known radial engines. A radial engine generally has a crankshaft and pistons disposed in a radial relationship about the crankshaft. The pistons are 15 disposed to engage the crankshaft such that there is correspondence between the rotation of the crankshaft and the reciprocating motion of the pistons in their cylinders.

In one known radial engine, the crankshaft is substituted by a crank that is configured to permit the pistons to be aligned with one another along the length of the rotational axis of the crank. As the pistons are aligned, the normal stepped-waveform 20 crankshaft configuration cannot be used. Usually this is substituted by a cam-and-follower arrangement to permit a translation between the linear reciprocating motion of the pistons and the rotational motion of the crank. It will be appreciated that, due to the alignment of the pistons, this arrangement provides a significantly greater degree of compactness than in the case of engines where the pistons are positioned at spaced 25 intervals along the length of the crankshaft.

However, due to the usual cam-and-follower arrangements, such radial engines have disadvantages relating to the reaction forces exerted by the cranks on the pistons, via the followers and connecting rods. Further disadvantages relate to the methods adopted for effecting suitable engagement between the followers and the cranks. For 30 example, certain of these engines have required cranks with particularly complex structures and complex means for providing lateral support to the connecting rods. Such

structures are expensive and difficult to produce and hence are often not suitable for large-scale production.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to overcome or ameliorate one or more of 5 the disadvantages of the prior art, or to provide a useful alternative.

Therefore, according to the invention there is provided a radial engine including:  
an engine block having a central aperture;  
a drive shaft extending through said aperture;  
a planar cam plate fixedly mounted on said shaft;  
10 a pair of spaced opposed walls extending from the surface of said plate to define a substantially "figure 8" shaped continuous loop;  
at least one cylinder fixed with respect to said block and extending radially outwardly from said block;  
a reciprocatable piston slidably mounted within said cylinder;  
15 a connecting rod fixedly connected at one end to said piston and having an opposite free end;  
a cam follower translationally fixed with respect to said connecting rod, said cam follower being engaged with at least one of said walls, such that reciprocation of said piston rotates said plate and said shaft.  
20 Preferably, the loop is defined by a groove in the plate and the cam follower projects into the groove.

Preferably, the cam follower is a pin. More preferably, the pin is included on a linear slider bearing fixedly connected to the free end of the connecting rod. Even more preferably, the slider bearing includes a prismatic body having an aperture for mounting 25 the pin.

The engine preferably includes a guide for translationally guiding the connecting rod. More preferably, the guide is defined by a complementary bore in the block, the bore having a sidewall for laterally supporting the connecting rod during reciprocation of the piston.

30 Preferably, the sidewall includes a longitudinal slot through which the pin projects into the groove.

Preferably, the engine includes an even number of said cylinders, regularly circumferentially spaced around the periphery of the engine block.

In another embodiment, the walls define a projecting ridge defining the loop and the cam follower includes a channel into which the ridge extends, the follower being configured to traverse the ridge to rotate the plate.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5 Preferred embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a side elevation of an engine according to an embodiment of the present invention;

Figure 2 is an elevation of the engine of Figure 1 in the direction of arrow II;

10 Figure 3 is a side elevation of an engine block of the engine of Figure 1;

Figure 4 is an elevation of the block of Figure 3 in the direction of arrow IV;

Figure 5 is a side elevation of an engine block cover forming part of the engine of Figure 1;

Figure 6 is an elevation of the cover of Figure 5 in the direction of arrow VI;

15 Figure 7 is a side elevation of a further engine block cover forming part of the engine of Figure 1;

Figure 8 is an elevation of the cover of Figure 7 in the direction of arrow VIII;

Figure 9 is a side elevation of part of a crank forming part of the engine of Figure 1;

20 Figure 10 is an elevation of the part of Figure 9 in the direction of arrow X;

Figures 11 and 12, 13 and 14, 15 and 16, and 17 and 18, are side elevations and end elevations, respectively, of various components of the engine of Figure 1;

Figure 19 is a part-exploded perspective view of another embodiment of an engine according to the invention;

25 Figure 20 is a perspective view of the engine of Figure 19, shown with the cam plates removed; and

Figure 21 is a perspective view of the linear slider bearing of Figures 19 and 20.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 to 18 of the drawings and according to a first embodiment of 30 the invention, a radial engine 1 includes an engine block 2 with a circular recess 3 on each side of the block, and a web 4 dividing the recesses. Each one of a pair of cam plates 6 and 7 is supported on a cylindrical shaft 8 (see especially Figures 11 and 12) for

rotation about an axis 9. Each plate 6 and 7 is spaced on an opposite side of the web and is accommodated in a respective one of the recesses 3. Eight cylinders 10 are regularly circumferentially spaced around the periphery of the engine block and fixedly connected to the engine block. The cylinders extend radially outwardly with respect to the axis 5 from adjacent the plates. For the sake of simplicity, the cylinder heads and the fuel/air intake manifolds have been omitted from the drawings.

The plates 6 and 7 are substantially enclosed within the recesses 3 by a pair of engine block covers 11 and 12. The engine block 2 and the covers 11 and 12 are fixed with respect to each other by Allen screws 13 which pass through holes 14 in the covers 10 and block. The skilled addressee will appreciate that the parts of the engine described above may be of various materials, including, where appropriate, brass, steel, or aluminium. Furthermore, the parts may, as appropriate, be cast or machined. The cylinders 10, in one embodiment, are bolted to the engine block 2, although in other embodiments the cylinders may be cast or machined to be integral with the engine block.

15 The engine block 2 has a circular central aperture 15. Each one of a plurality of bores 16 of generally circular cross-section extends radially from the outer rim 17 of the engine block 2 to the central aperture 15. The bores 16 are defined by sidewalls 18, and have a cross-sectional diameter greater than the thickness of the web 4. Accordingly, the sidewalls have gaps that open through the opposite outer surfaces of the web to define a 20 longitudinal slot 19.

The shaft 8 has a cylindrical broad shaft-portion 20 and a cylindrical narrow shaft-portion 21. The narrow shaft-portion 21 is of smaller diameter than the broad shaft-portion 20 so that there is a shoulder 22 between the portions. The narrow shaft-portion 21 includes a radially outer screw thread 23 that extends from a free end 24 of the 25 narrow shaft-portion towards a position closer to the shoulder 22.

The plates 6 and 7 are disposed to face each other with the web 4 between them. Moreover, the plates 6 and 7 are spaced apart by a spacer 25 (see especially Figures 15 and 16) that extends through the central aperture 15 of the engine block 2.

Each plate includes a pair of spaced opposed walls 26 extending from the plate 30 surface to define a continuous loop. In this embodiment, the walls are parallel and extend into the plate to define a substantially "figure 8" shaped groove 27 in the plate, as illustrated in Figure 9. In this embodiment, the grooves are machined into or formed on their respective plates. In alternative embodiments (not shown), the plate includes a

recess, the perimeter of the recess defining the outer wall of the groove. In these alternative embodiments, a complementary second plate member fits within the aperture to define the inner wall of the groove.

In another embodiment of the invention (not shown), the walls extend outwardly 5 from the plate surface to define a protruding continuous ridge and the cam follower includes a channel into which the ridge extends, the follower being configured to traverse the ridge as the plate rotates.

The plates are rotationally fixed with respect to each other by locating pins 28 (see Figures 17 and 18) disposed inside the perimeter of the grooves 27, such that the grooves 10 are aligned with each other.

A locking element 32 (see especially Figures 13 and 14), having a spigot-shaped portion 33 and a nut 34, is screwed onto the screw-threaded end 23 of the narrow shaft portion 21. The nut 34 is secured against the plate 5 to hold both plates captive against the shoulder 22. In one embodiment, the plates 6 and 7 are constrained to rotate with the 15 shaft 8 by means of a key and keyway (not shown). In another embodiment, this is achieved by means of splines (also not shown).

The engine block cover 12 has a socket-shaped portion 35 that defines a central aperture 36 through which the broad shaft-portion 8 extends as a running fit.

The other engine block cover 11 has a stepped-socket-shaped portion 37 that has a 20 larger-diameter part 38 and a smaller-diameter part 39. The larger-diameter part 38 accommodates the nut 34 of the locking element 32. The smaller-diameter part 39 defines a central aperture 40 through which the spigot-shaped portion 33 of the locking element 32 extends as a running fit.

It will be appreciated that rotation of the plate 5 about the axis 9 is enabled by the 25 running fits of the spigot-shaped portion 33 of the locking element 32 and the broad shaft-portion 8 in the apertures 40 and 36, respectively. In a further embodiment (not shown) the spigot-shaped portion 33 and the broad shaft-portion 8 may be provided with bearings to facilitate rotation of the plates 6 and 7. Furthermore, seals (not shown) may be provided to retain lubricant at positions where one surface rotates on another.

30 A reciprocatable piston 41 is slidably mounted within each cylinder 10. Each piston moves along a respective straight piston axis 42. Axes 42 each extend radially outwardly perpendicular to the crank axis 9 and lie in a common plane. One side of each piston 41 forms part 43 of a combustion chamber. On the other side of each piston 41,

there is attached one end 44 of a connecting rod 45. The connecting rods 45 extend along the complementary bores 16 in the engine block and are laterally supported by the sidewalls 18. It will therefore be understood that the connecting rods 45 are angularly immovable relative to the respective piston axes 42.

5 Each connecting rod 45 has an opposite free end 46 and an aperture 47 adjacent the free end. A respective cam follower in the form of a pin 48, is located in each aperture 47. Each pin 48 has opposite free ends and a central portion between the ends. The central portion of each pin is located in the apertures and the pin free ends project through the slot 19 and into the groove 27.

10 In use, each piston 41 is powered in a manner conventionally employed in internal combustion engines (although the cylinder heads and the intake and exhaust valves and/or ports are not shown in the drawings). The resulting reciprocating motion of the pistons 41 along their respective piston axes 42 involves corresponding motion of the connecting rods 45. It should be noted that the slots 19 extend substantially parallel to the respective piston axes 42. Thus, when the pistons 41 reciprocate, the free ends of the cam-follower pins 48 traverse the slot 19 and cammingly engage the walls 26. In the present, preferred embodiment, each pin 48 has a shoe at each of its free ends for engaging and guiding the pin along the walls 26. However, in another embodiment (not shown) each pin 48 is equipped with a roller for rolling along the walls 26.

15 20 The timing of the piston movement and the specific configuration of the grooves 27 are such that the pistons 41, via the connecting rods 45, drive the plates 6 and 7 in rotation about the crank axis 9, with the walls 26 acting as cam surfaces in engagement with the cam follower pins 48.

An alternative embodiment of the invention is illustrated in Figures 19, 20 and 21, 25 where corresponding reference numerals indicate corresponding features. For the sake of simplicity, a two-cylinder embodiment is shown with the cylinder heads and the fuel/air intake manifolds omitted. The grooves are shown as slots extending completely through the cam plates to enable ease of understanding of the assembly.

20 30 This embodiment functions essentially in the same manner as the embodiment described above. However, in this embodiment, a linear slider bearing 50 is fixedly connected to the free end of each connecting rod 45. The bearing includes a prismatic body 51 having an aperture (not shown) through which a respective one of the pins 48 extends. Each one of the pins extends beyond the extent of the body and into the plate

grooves 28. The bores 16 in the engine block are complementary with the shape of the bearings and extend completely through the web 4 to define a slot 53. Therefore, the bores have sidewalls perpendicular to the plane of the web. This configuration simplifies manufacture of the engine block, while maintaining the lateral support for the 5 connecting rods.

The configuration of the engine 1 in the embodiments described above is such that it is suitable for use as a two-stroke engine or a four-stroke engine.

Because the connecting rods 45 are guided in the bores 16, the lateral reaction forces exerted by the plates 6 and 7 on the cam-follower pins 48 is not communicated to 10 the pistons 41. Accordingly there is no specific requirement for the pistons 41 to be capable of withstanding the bending moments that may occur in conventional engines. Therefore, the piston skirts present in conventional engines can be reduced in length or omitted entirely, as in the embodiment being described.

Where the engine 1 is used as the type of two-stroke engine where the fuel-air 15 mixture is drawn into the area below the piston, because the connecting rods do not move from side-to-side as in a conventional two-stroke engine and because of the shorter or omitted skirts, a greater degree of compression can occur on the fuel-air mixture below the piston. Without wishing to be bound by theory, the applicant believes that, where a compression to 6 psi might be achieved in the case of a conventional two-stroke 20 engine, a compression to 150 psi is achievable using an engine in accordance with an embodiment of the present invention.

Generally, if the exhaust port were lowered in a two-stroke engine of the type being discussed, this would be advantageous in one sense, as it would prolong the power stroke, with a resulting increased torque. However, in another sense, it would be 25 disadvantageous as it would delay the evacuating of exhaust gases, which would in turn reduce the ability to transfer fuel-air mixture from below the piston to the combustion chamber. This effect would be particularly significant in cases where high engine revolution rates were required. The greater compression permitted by an engine according to an embodiment of the present invention would, however, increase the 30 potential rate of transfer of fuel-air mixture from the area below the piston to the combustion chamber. As the resulting forcing of fuel-air mixture into the combustion chamber would also force the burnt gases out through the exhaust port, the effect of delaying the exhausting of spent gases would be offset. Accordingly, embodiments of

the present invention lend themselves to lowering the ports, with the associated advantage of longer power strokes and higher torque, without the disadvantage of reduced rate of transfer of gases.

In addition to the above, the shorter or omitted skirts would result in the pistons 5 being lighter than those in conventional engines. The use of lighter pistons in conjunction with the radial configuration would reduce or eliminate the need for counterweights or crankshaft bob weights which may be required in conventional engines to achieve suitable balancing. The lighter pistons would also reduce stresses, and the power losses associated with overcoming inertia.

10 A further advantage of the arrangement envisaged by the present invention is that the grooves 27 could be configured for each piston 41 to reach top dead centre twice for every single revolution of the plates 6 and 7 and hence of the output shaft 8. This may permit greater compactness, as the stroke would effectively be doubled without increasing the physical size of the engine.

15 It will be appreciated that the features of the present invention, at least in preferred embodiments, provide an effective way of achieving the cam-and-follower structure required for a radial engine of the present type. Notable among these features are the opposed walls 26 which form an integral part of the cam plates 6 and 7, the grooves 27 defined by these walls, the bores 16 in the engine block 2 and the slots 19 in the 20 sidewalls 18 through which the cam follower pins 48 extend. These features provide a relatively simple balance between, on the one hand, the desired conversion from translational motion of the pistons 41 to rotational motion of the crank 5 with the pistons being aligned with one another for compactness, and on the other hand, effective lateral support of the connecting rods 45 and minimisation of bending moments on the pistons.

25 An advantage of the engine according to an embodiment of the invention is that the cylinders are arranged in opposed pairs and therefore provide for a natural balancing of the engine. It will be appreciated that, although 8 cylinders are shown in the described example, other multiples of two cylinders can be used instead.

The invention is described above as an internal combustion engine in which the 30 pistons are configured to drive the cam plates. However, it will be appreciated that the invention is not limited to this particular application. For example, the engine may be configured so that the plates are driven by a prime mover, with the plates in turn driving

the pistons in their reciprocating motion. Such a construction may constitute, for example, a pump apparatus where each piston constitutes an individual pump.

Although the invention has been described with reference to a specific embodiment it will be appreciated by those skilled in the art that it may be embodied in 5 many other forms.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A radial engine including:
  - an engine block having a central aperture;
  - a drive shaft extending through said aperture;
  - 5 a planar cam plate fixedly mounted on said shaft;
  - a pair of spaced opposed walls extending from the surface of said plate to define a substantially "figure 8" shaped continuous loop;
  - 10 at least one cylinder fixed with respect to said block and extending radially outwardly from said block;
  - 15 a reciprocatable piston slidably mounted within said cylinder;
  - a connecting rod fixedly connected at one end to said piston and having an opposite free end;
  - a cam follower translationally fixed with respect to said connecting rod, said cam follower being engaged with at least one of said walls, such that reciprocation of said piston rotates said plate and said shaft.
2. An engine according to claim 1 wherein said loop is defined by a groove in said plate and said cam follower projects into said groove.
3. An engine according to claim 2 wherein said cam follower is a pin.
4. An engine according to claim 3 wherein said connecting rod includes an aperture 20 adjacent its free end for mounting said pin.
5. An engine according to any one of the preceding claims including a guide for translationally guiding said connecting rod.
6. An engine according to claim 5 wherein said guide is defined by a complementary bore in said engine block and the sidewall of said bore laterally supports said connecting 25 rod during reciprocation of said piston.
7. An engine according to claim 6 wherein said sidewall includes a longitudinal slot through which said cam follower projects.
8. An engine according to any one of the preceding claims including a spaced opposing pair of said plates rotationally fixed with respect to each other by locating pins, 30 wherein said walls on one said plate are aligned with the walls on the opposing plate.
9. An engine according to claim 8 wherein said cam follower engages at least one of said walls.

10. An engine according to any one of the preceding claims wherein said cam follower includes a roller for rolling engagement with at least one of said walls.
11. An engine according to any one of the preceding claims including a plurality of said cylinders.
- 5 12. An engine according to claim 11 including an even number of said cylinders, regularly circumferentially spaced around the periphery of said engine block.
13. An engine according to claim 1 wherein said walls define a continuous projecting ridge defining said loop and said cam follower includes a channel into which the ridge extends, the follower being configured to traverse the ridge to rotate the plate.
- 10 14. An engine according to claim 3 wherein said pin is included on a linear slider bearing fixedly connected to the free end of said connecting rod.
15. An engine according to claim 14 wherein said bearing includes a prismatic body having an aperture for mounting said pin.
16. An engine according to claim 15 including a guide for translationally guiding said bearing.
- 15 17. An engine according to claim 16 wherein said guide is defined by a complementary bore in said engine block and the sidewalls of said bore laterally support said bearing during reciprocation of said piston.
18. An engine according to claim 17 wherein said sidewalls include a longitudinal slot through which said pin projects into said groove.
- 20 19. An engine according to claim 18 wherein said slot is defined by a pair of spaced parallel sidewalls extending completely through said web.
- 20 21. An engine according to any one claims 14 to 19 including a spaced opposing pair of said plates rotationally fixed with respect to each other by locating pins, wherein the groove on one said plate is aligned with the groove on the opposing plate.
- 25 22. An engine according to any one of claims 14 to 21 including a plurality of said cylinders.
- 30 23. An engine according to claim 22 including an even number of said cylinders, regularly circumferentially spaced around the periphery of said engine block.

- 12 -

24. An engine substantially as herein described with reference to any one of the accompanying drawings.

Fig. 1

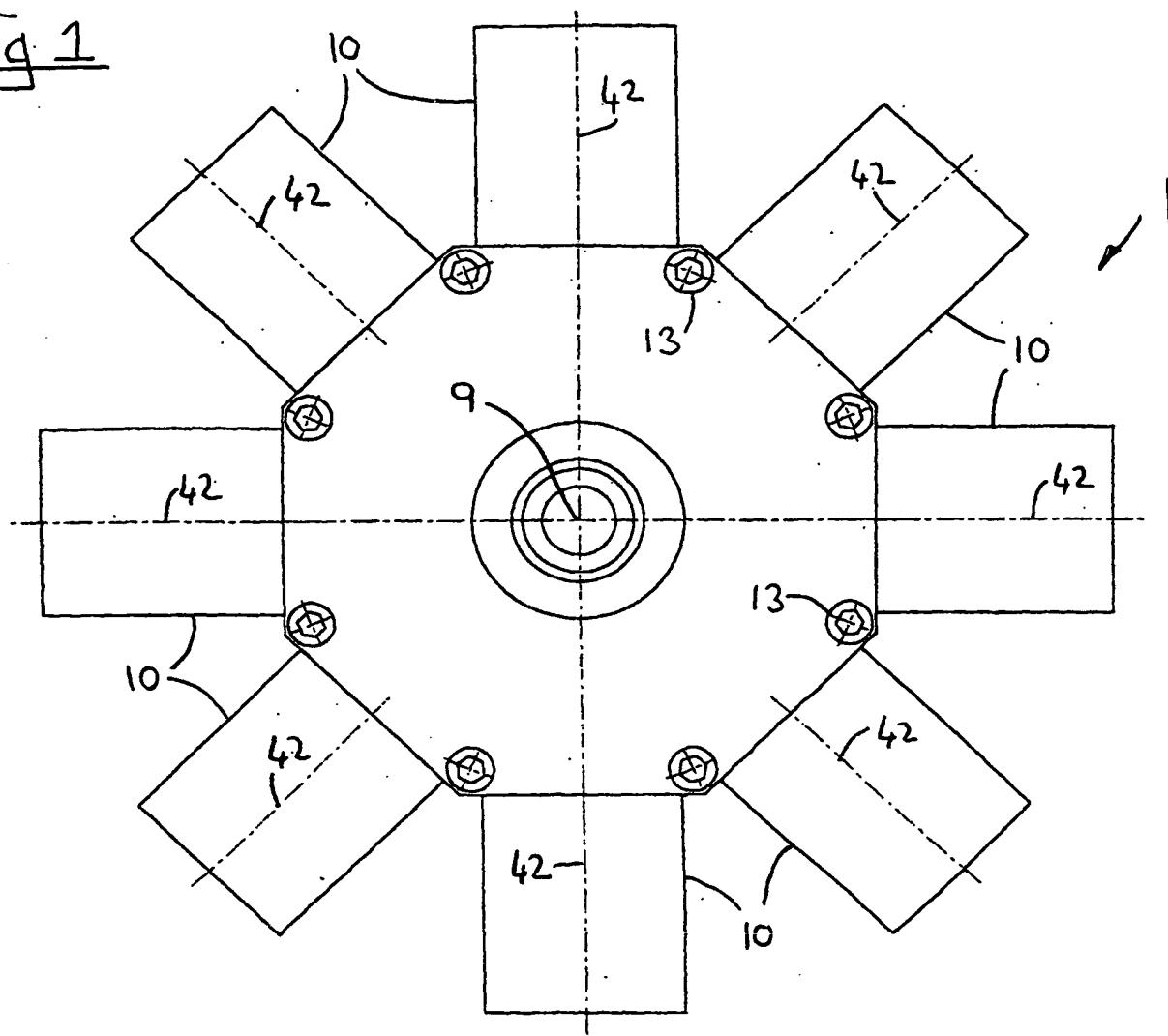


Fig 2

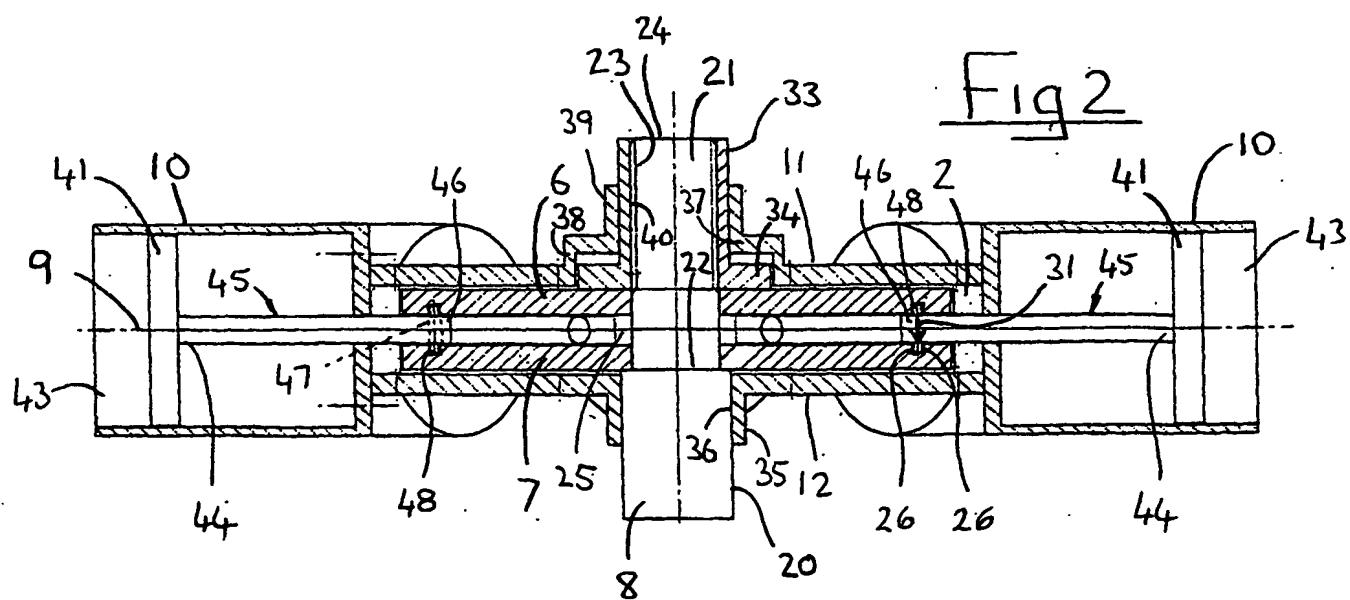


Fig 3

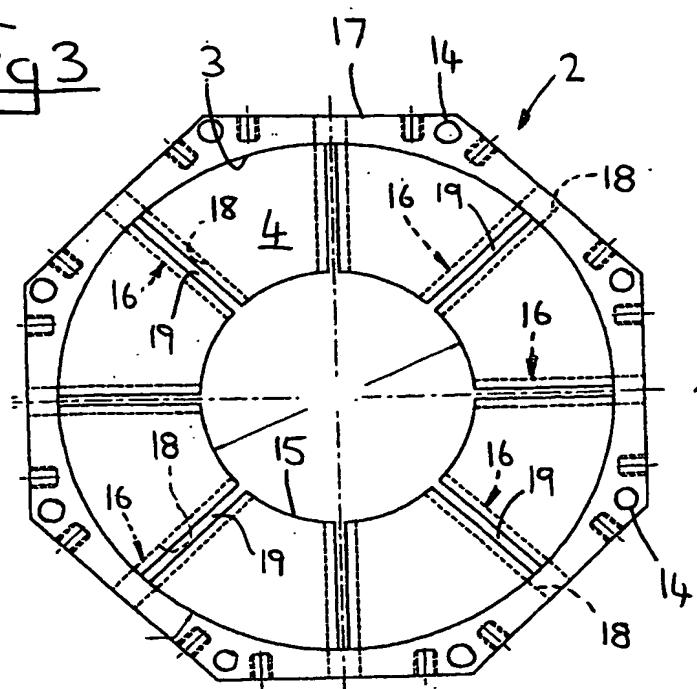


Fig 4

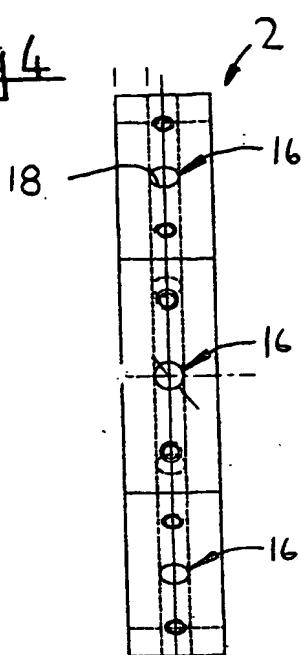


Fig 5

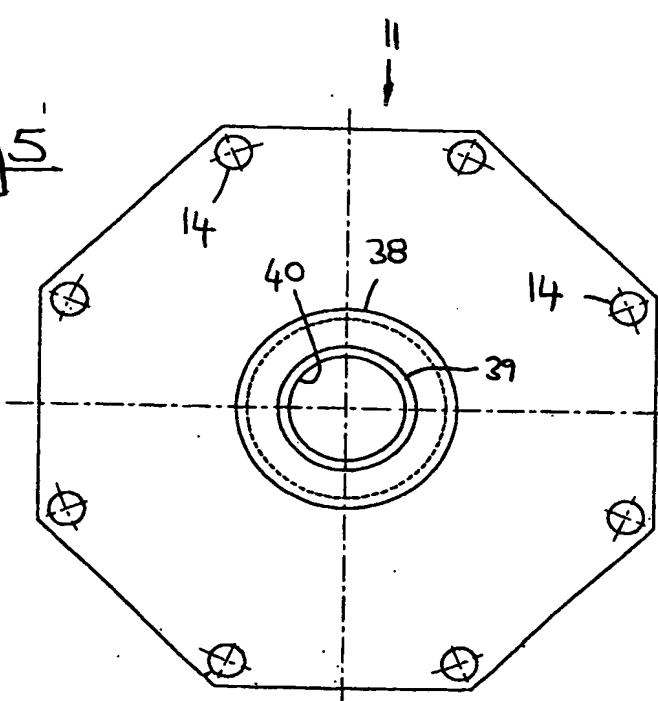


Fig 6

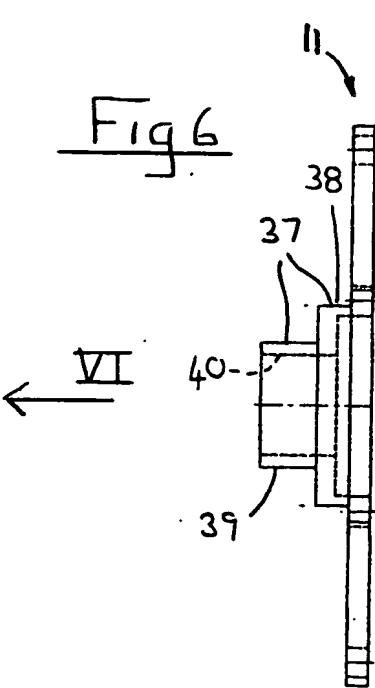
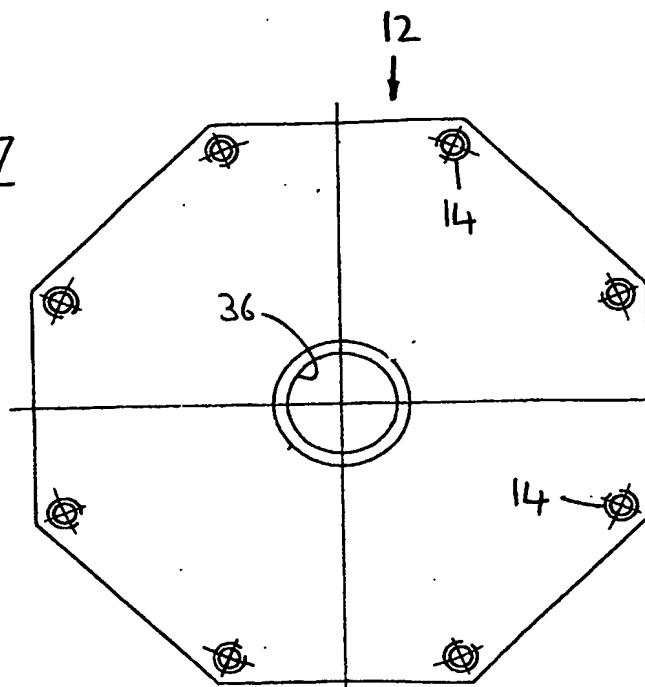
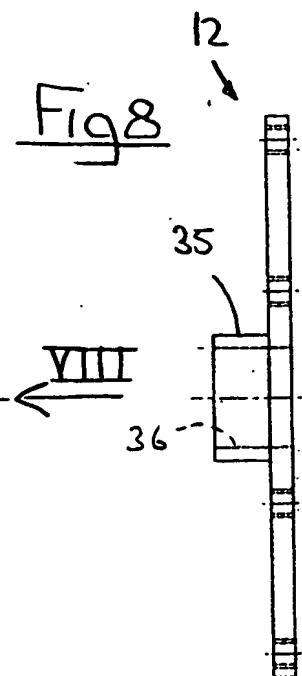
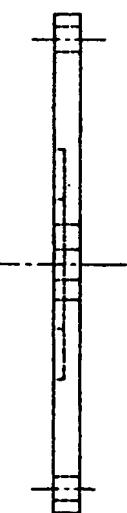
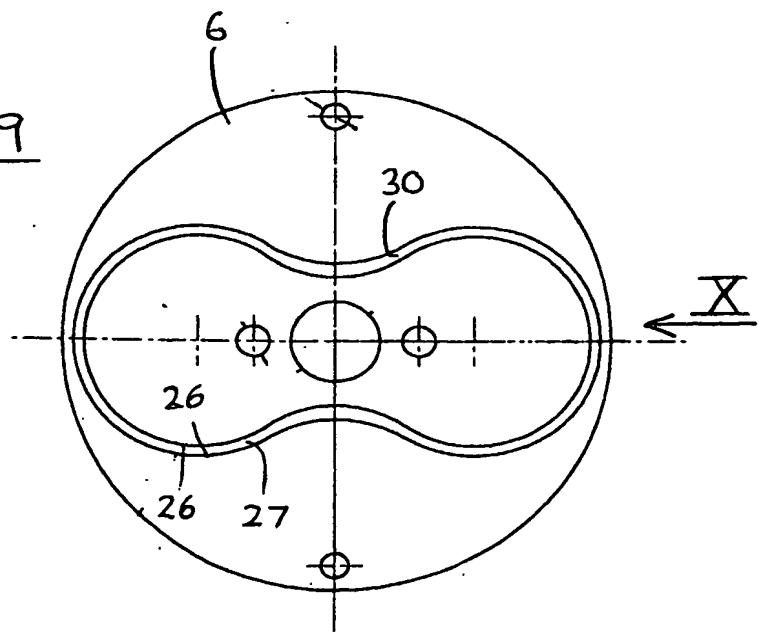


Fig 7Fig 8Fig 9

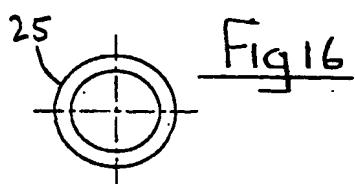
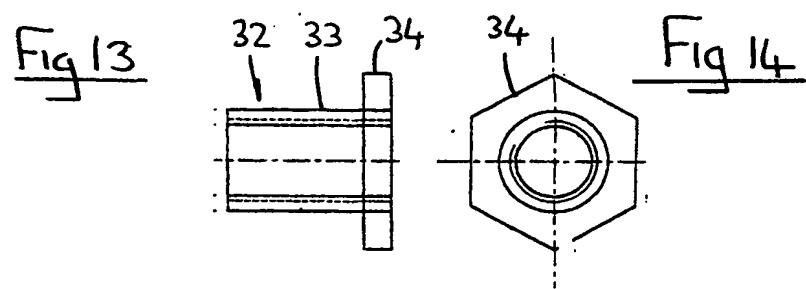
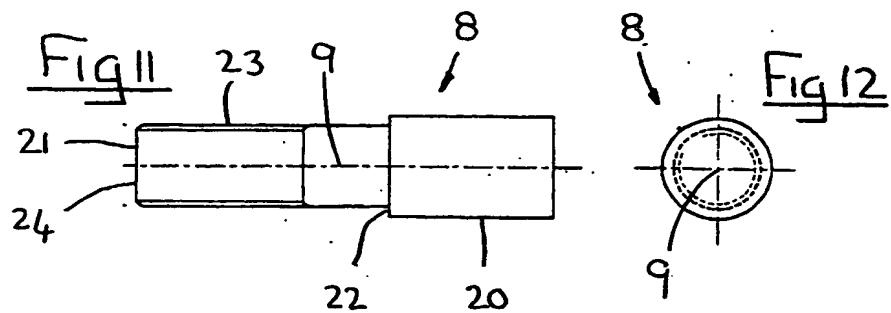


Fig 17

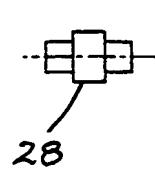


Fig 18

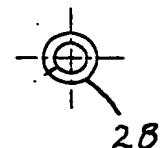


Fig 15

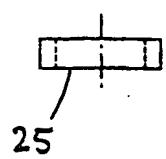


FIG. 19

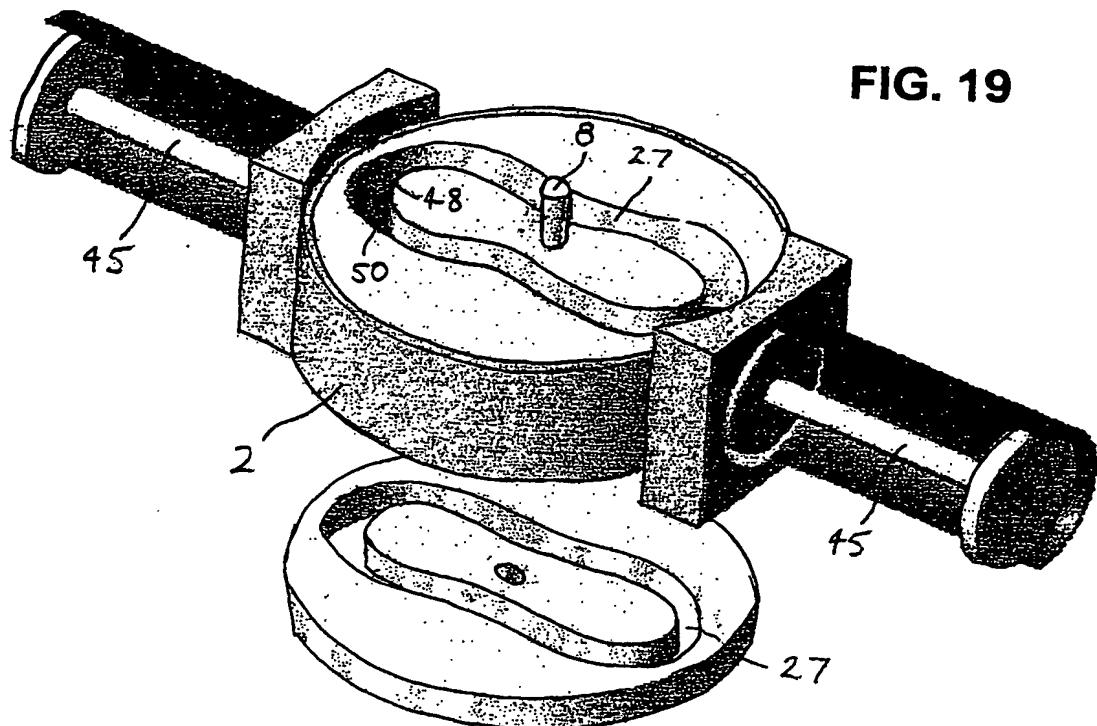
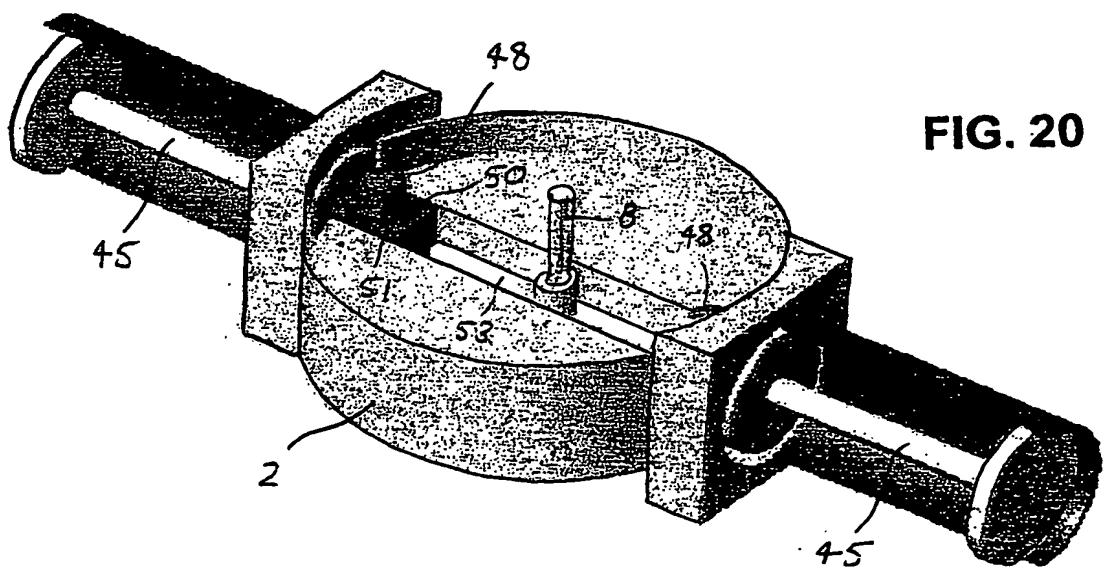
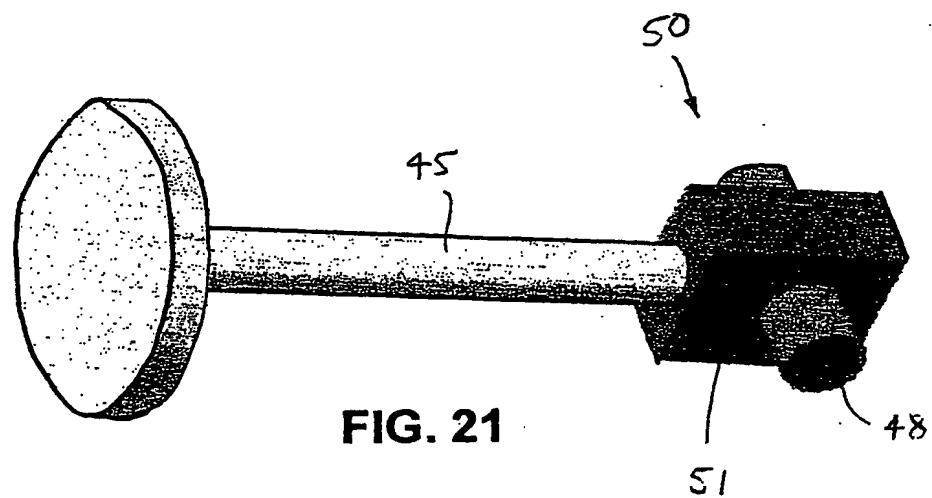


FIG. 20



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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU02/00513

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: F01B 1/06, 9/06, F02B 75/32, F16H 21/36, 25/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI: IPC - F02B 75/32, F01B 9/06 and keywords (SLOT, GROOVE etc)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,Y	EP 64726 B1 (ARENNDT) 31 July 1985 Whole document	1-7, 10-12
X,Y	Derwent Abstract Accession No. 2001-111161/12, Class Q51, RU 2157892-C2, (ZAMARATSKII YU) 20 October 2000 abstract	1-2, 10-12
Y	US 2407859 A (WILSON) 17 September 1946 Whole document	1,5-7, 10-12

 Further documents are listed in the continuation of Box C See patent family annex

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Date of the actual completion of the international search 21 May 2002	Date of mailing of the international search report 29 MAY 2002
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer <b>KURT TOBLER</b> Telephone No : (02) 6283 2469

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU02/00513

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 1667213 A (MARCHETTI) 24 April 1928 Whole document	1, 5-7, 10
P,Y	US 2001/0017122 A1 (FANTUZZI) 30 August 2001 Whole document	1
A	US 4465042 A (BRISTOL) 14 August 1984 Whole document	
A	Derwent Abstract Accession No. 98-455231/39, Class Q51, Q52, RU 2104401-C1, (KOSUKHIN), 2 October 1998 abstract	

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
**PCT/AU02/00513**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
EP	64726	DE	3118566	JP	57193723
US	4465042	US	4363299	DE	3208249

**END OF ANNEX**